Preferences for Water Treatment Provision in Rural India: Comparing Communal, Pay-per-Use, and Labor-for-Water Schemes

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Abstract

Using a contingent valuation survey, this research identifies villagers' willingness to pay (WTP) towards the operation and maintenance of water treatment plants in eleven villages in Maharashtra with existing facilities. Preferences were elicited using three different payment mechanisms: 1) a monthly fee, 2) labor (time) contributions, and 3) a pay-per-container mechanism. Results show low levels of support for the pay-per-container scheme (51% stated positive WTP towards this option), whereas the communal mechanisms were more popular (86.7% and 87.3% stated positive contributions). This study concludes that the long-term viability of water treatment in Maharashtra is weak, as few scenarios provide adequate revenue to properly operate and maintain the infrastructure.

Keywords: fluoride; contingent valuation; India; pay-per-use; water treatment

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1. Introduction

Geogenic contamination of drinking water is a major health issue in India, which relies heavily on groundwater supplies, most of which were developed to tackle problems of fecal contamination. High levels of naturally-occurring fluoride in the groundwater makes India one of the countries most impacted by fluoride-contaminated water, with contamination prevalent in 20 states across the country (National Health Portal India, 2016). Treatment to remove fluoride is typically costly due to the need for regular maintenance, active operation of treatment technologies, regular replacement of parts, and other associated costs such as electricity supply for certain technologies. In rural areas, these costs may pose a significant barrier to the provision of safe, fluoride-free drinking water. In the state of Maharashtra, where this study is based, the regional government initially provides financial support towards the implementation and operation of communal rural treatment plants (discussed in Section 2); however, the aim is to move towards 'demand-driven' systems that are financed by users in the long term (World Bank, 2010, 2014). This mirrors similar shifts towards user-based financing of water provision taking place across the developing world (OCED, 2011; Rogers, De Silva, & Bhatia, 2002).

Identifying user preferences (i.e. willingness to pay) for water treatment is therefore a critical question, as this will help determine whether there is demand for water treatment and whether the costs of operation and maintenance of rural treatment systems can be covered by user fees. For example, we estimate (Section 6) a fluoride water treatment facility with between 500-3000 L of tank volume would cost approximately 92-300 Indian rupees (INR) to operate every day. Given this range of costs, it is essential to identify the perceived benefits of fluoride-free water to rural users. This is a critical question; if villagers do not sufficiently value having access to treated water, then the continued deployment of these treatment plants around fluoride-affected villages may not be economically viable.

However, user-financed systems may take different forms entailing quite different payment mechanisms and water access options, which may affect acceptability and preferences. On the one hand, there are community-owned water facilities in which all users contribute regular payments towards upkeep and management; access to water in these models is largely open to all and there are generally no restrictions on the amount each household can consume. This is the approach currently promoted in Maharashtra. An alternative model that is gaining support across the developing world including India involves pay-per-use systems. Access to water via this model is restricted to those who pay, and the amount consumed is determined by payment amount.

Despite growing popularity, to the best of our knowledge there have been no studies identifying acceptability or preferences associated with pay-per-use schemes. Most studies investigate attitudes of consumers for water free from geogenic contamination, typically focusing choices between two sources, neither of which require payment (Huber & Mosler, 2012; Inauen, Hossain, Johnston, & Mosler, 2013; Madajewicz et al., 2007; Mosler, Blochliger, & Inauen, 2010; Van Geen et al., 2002). Only one study has been identified that estimates WTP for the treatment of fluoride-contaminated drinking water; however, it narrowly focuses on a specific treatment technology researched by the group conducting the study, which limits its generalizability to other contexts (Roy & Chakraborty, 2014), .

The present study adds to this limited literature by identifying WTP for the treatment of fluoride-contaminated water in rural villages in the state of Maharashtra provided via communal and pay-per-use schemes. Our main contributions to the literature thus involve, i) identifying acceptability of and preferences for treated water associated with pay-per-use schemes, ii) a comparative analysis of acceptability and preferences for communal versus pay-per-use schemes, and iii) identifying the economic feasibility of different rural drinking water treatment models. To do this, we estimate preferences using three different scenarios and associated payment mechanisms: two of which are associated with 'communal' systems, and the third associated with the pay-per-use system.

The first mechanism, modelled on the current approach used in Maharashtra, involves a communal scheme which provides water to everyone, and which requires monthly payments by all households. This type of scheme may be considered a quasi-public good, in which there may be congestion issues at peak times of day, but which, for the most part, is non-excludable and potentially subject to free riding. Successful communal systems typically depend on collective action, policing within the community, and punishment of non-contributing households to sustain financial contributions over time. Despite these hurdles, community-based water treatment technologies are the favored water provision approach of the reform policy in India (Brunner, Lele, Starkl, & Grassini, 2010).

The second mechanism takes into account that villagers may hold positive values for communally-managed water treatment plants, and yet are unable or unwilling to make monetary contributions. This might occur if there are constraints on cash availability – such as in low-income and subsistence communities (e.g. O'Garra, 2009). In these situations, contributions of labor time might serve as a viable alternative to monetary contributions (e.g. O'Garra, 2009; Gibson et al., 2016). Indeed, it is common practice in many developing countries for individuals to contribute some of their time towards social and community schemes; examples include Vietnam (Glewwe, Agrawal and Dollar, 2014), Fiji (O'Garra, 2009) and Rwanda (Kalisa, 2014). Thus, the second mechanism used to identify preferences for water treatment, involves contributions of time towards the operation and maintenance of the water treatment plant. Willingness-to-work for water provision has been examined in Abramson et al. (2011) and Vasquez (2014); in both studies, derived welfare values from labor-contributions were comparable to those derived from monetary contributions, suggesting both mechanisms might provide realistic options for users to pay for water.

The third mechanism involves the 'pay-per-use' scheme in which villagers pay for each container of water collected. Treated water is thus privatized in that it is only accessible to those who pay, and the amount provided is proportional to the amount paid. This demand-driven approach to water provision first appeared in Indian water development policies in the early 2000s (Vandana, 2013); however, it is the recent rise in popularity of water ATMs across India (Aiyappa, 2014; Gupta, 2014; Kapoor, 2015; Press Trust of India, 2014; TNN, 2016) that makes evaluation of user acceptance of and WTP for these schemes especially relevant. This "new" model of water delivery is similar to the familiar water kiosk model popular throughout Asia and Africa, which is marketed as giving the economically poor more choice and control as water is purchased by volume as needed (Collignon & Vézina, 2000; Opryszko, Huang, Soderlund, & Schwab, 2009). Contributions to this type of scheme may reflect the preferences of individuals with low levels of trust in others or in the ability of the community to successfully manage the communal treatment plant. It may also reflect preferences of those who particularly value excluding potential free-riders. There has been extensive debate in the literature about the merits and challenges of pay-per-use water schemes, with concerns about the exclusion of low-income households from water rendered unaffordable (Budds, McGranahan Asia, America, & McGranahan, 2003; Zaki & Amin, 2009); yet, there are many different organizational models to the ATM/kiosk ranging from privately-owned to community ownership and management of the resource. Our aim here is to identify acceptance levels and preferences for treated water from a volume-based purchasing approach, which essentially represents a private good.

As noted, to the best of our knowledge, this is the first study to identify preferences for a pay-per-use model of drinking water provision. Given the increasing popularity of this provision model, and the extensive debate about its potential benefits, the estimation of attitudes towards and preferences for this type of water provision approach represents a significant contribution to the literature and to the policy debate on rural water provision.

By identifying and comparing preferences elicited under these three different mechanisms we can assess the feasibility of different provision mechanisms for rural drinking water treatment plants. Given the low success rate of water treatment and reliable service delivery in India (Pattanayak, Yang, Whittington, & Bal Kumar, 2005; Pierce, 2017; Zérah, 2000) –and around the world (Etmannski & Darton, 2012; Inauen et al., 2013)– these findings represent a critical input into policy-decisions regarding how best to secure long-term success of water treatment systems in rural communities.

The rest of the paper is organized as follows: Section 2 and 3 describe the background to the study, the location, and the methodologies of the research. Section 4 details the survey population characteristics, including attitudes and knowledge regarding water, fluoride contamination, and the installed water treatment units. Section 5 reports user preferences for treated water by the three major payment schemes discussed above. Section 6 details the interval regression models and analysis which is then used in

Section 7 to evaluate the economic viability of these technologies. Finally, we present conclusions to our research in Section 8.

2. Description of study site

In India, the government limits fluoride to a threshold of 1.0 mg/L F with a secondary permissible limit of 1.5 mg/L F when no other source is available (BIS IS-10500). In Maharashtra, some rural locations contain concentrations in excess of 5 and even 13 mg/L (Duraiswami & Patankar, 2011; Madhnure, Sirsikar, Tiwari, Ranjan, & Malpe, 2007). Of Maharashtra's 35 districts, six contain 133 of the most impacted villages, with the largest cluster in Yavatmal (see Table S 1 in Supplementary Information) where this study is based.

Unfortunately, fluorosis has no direct cure; avoidance or development of defluoridation treatment are the only mitigation approaches. The Maharashtrian Government considers treatment as the last method of action in combatting fluoride in a community, exhausting other options such as availability of alternate sources and the feasibility of supplying piped water prior to implementing a treatment scheme (Andey et al., 2013; Government of Maharashtra, 2011). When there are no alternative sources and no immediate potential for piped water, the government issues 3-5 year contracts to a private company to build and maintain a defluoridation treatment facility in the community. After this initial period, the treatment facilities are then turned over to the communities. This handover process is part of recent policy reforms aimed at moving many development decisions to the *Gram Panchayat* (village council) level. Examples of such policy reforms include the Government of India Sector Reform Pilot Programme (initiated in 1999), Swajaldhara (initiated in 2002), the Prime Minister's

Gramodaya Yojana-Rural Drinking Water Programme (PMGY Programme) (initiated in 2000), and the World Bank-aided Jalswarajya Project (initiated in 2003) (Government of India, 2007). The transfer includes moving responsibility regarding planning, implementation, operation, and maintenance to the village level.

We conducted our study in eleven villages (**Figure 1**) located in the district of Yavatmal, in the state of Maharashtra, which, as noted, has one of the highest concentrations of villages with fluoride-contaminated water sources in the region. The selected villages met the following criteria: (1) they contain identical technologies (electrocoagulation) for fluoride treatment, and (2) the water treatment facilities were in the process of being turned over from government-subsidized private companies to the communities between October-December 2014. These criteria ensured technical differences in the operation and maintenance of the treatment plants, and differences associated with the timing of the transition from government-subsidized to community-owned water treatment systems were controlled for, and would not represent a source of variation in the study.

[Figure 1: Location of 11 project villages within the Yavatmal District in eastern Maharashtra.]

3. Materials and methods

3.1 Survey design

To estimate preferences for treated drinking water in each of the research villages, we used a contingent valuation (CV) survey (Bateman et al., 2002). The CV question was embedded in a survey divided into six major sections identifying: 1) household drinking water sources, quantity of water collected, and perceived quality of drinking water; 2) household and individual practices relating to WASH indicators (water, sanitation, hygiene); 3) knowledge about fluoride, fluorosis, illnesses from drinking water and general WASH knowledge; 4) knowledge about the function of the defluoridation water treatment plant and the role of the community in managing it; 5) WTP for fluoride-treated water per month (WTPm), and per container (WTPc) and willingness to contribute time (WTcT) as an in-kind contribution, and finally, 6) socio-economic information.

To dispel fears of exclusion and corruption, the WTP question was embedded in a scenario which stressed everyone in the village, including women, were important for the water committee to succeed; additionally, we asked respondents to assume the water committees were fair, honest and responsible (see Supplementary Information for more details).

Preferences for fluoride-treatment facilities were then elicited via three different payment schemes, in the following order: 1) per month monetary contributions (WTPm), 2) per container monetary contributions (WTPc), and 3) daily contributions of time (WTcT). A binary response filter was used for each payment mechanism to identify those willing to pay towards the water treatment plant. Those who indicated a positive WTP, were asked to select their preferred contribution using a payment ladder approach[i] (Bateman et al., 2002). This involved asking respondents to choose their maximum WTP or willingness to contribute time (WTcT) from a series of amounts read out by the interviewer, starting at zero and increasing by discrete amounts to a maximum. The maximum values presented to respondents were as follows: 300 rupees per month for WTPm; 250 rupees per container for WTPc; 8 hours per day for the

WTcT mechanism. In all three cases respondents were capable of pledging more money or time as a “more” category was included on the ladder as well.

At the time of our survey, households had not yet started contributing towards their water treatment plants. These were either still under government contract, or the first payment had yet not been charged. Therefore, we expect no bias in terms of experience making payments.

We note that, in the pay-per-container (WTPc) scenario, the water source is presented as a community good owned and operated by the community, with the difference being that individuals can only extract a specific volume per payment. We opted to use this particular scenario rather than a company-owned scheme to avoid introducing additional sources of variation in the scenario in comparison to the other scenarios. Attitudes towards company-ownership would likely influence WTP for water treatment, and we mainly wanted to explore preferences for a privatized resource. Additionally, the policy in Maharashtra is specifically to deploy community-based treatment plants, hence our scenario adhered to this model of water treatment. We acknowledge the limitations of this scenario in terms of providing specific guidance about WTP for company-owned pay-per-container schemes; our approach focuses on preferences for access and payment options, and future studies could focus on preferences for different providers of treated water.

Reasons for non-payment were elicited after the valuation section (see Supplementary Information). The entire valuation scenario is included in the Supplementary Information Valuation Scenario.

3.2 Data Collection

Overall, 455 surveys each lasting 30 min on average were administered across the survey villages from 15-27 November 2014. These were conducted in Marathi by enumerators from the Vidarbha region, who had been trained over the course of a day and a half, including half a day of training in the field. The survey was administered on an electronic survey platform using the Open Data Kit application for android phones. The sample of households were selected using a random transect walk (Bennett, Woods, Liyanage, & Smith, 1991) in each village originating from the water treatment plant with each enumerator walking a different route. Participants in the survey were required to be an adult (18 years or older) who self-identified as a water collector for the household. Specifically, potential respondents were asked: "Can I speak to a head of the household who collects drinking water for the household?" Although females typically constitute the majority (82.7%) of primary water collectors in rural Indian households (IIPS and Macro International, 2007), we framed the initial filter question to broaden the gender inclusion in our survey, and thus account for the attitudes, knowledge and preferences of all water collectors, whether male or female.

A total of 31 surveys contained incomplete information and were therefore removed from survey analysis, resulting in a final sample of 424 respondents.

4. Sample Description

4.1 Socio-Economic Characteristics

Key socio-economic characteristics of respondents and their households are summarized in **Table 1**. Results show most of the sample was female (56%). However, a large portion (44%) of our respondents were male, and of these, 87% claimed to be a primary drinking water collector for the household. Thus, females were identified as the primary water collector in 60% of surveyed households, whilst males were identified as the primary collectors in 40% of households. This proportion of male water collectors is significantly higher than the population proportion of 10.7% for all of rural India, as per IIPS and Macro International (2007). However, India-wide average statistics may obscure local-level variation in water collection practices.

Notably, Yavatmal is classed as one of the country's most backward districts (National Institute of Rural Development, 2009), and as such, water collection activities may differ from those in more affluent regions. As can be observed in **Table 1**, the mean household income of our sample is significantly lower (two-tailed t-test: p-value=0.0001) than the average 5,289 INR for Yavatmal, indicating the villages in our study are particularly low-income. There is evidence that as a household becomes more economically poor, the likelihood of women being economically active increases (Blumberg, 2017). Additionally, in rural agricultural areas of India, men are more likely to engage in inconsistent day-laborer work as it pays a higher wage for men than it does for women (Bardhan, 2014; Desai & Jain, 1994). This, therefore, leaves many men home in the household while the female works the local field, conceivably creating an increased need for shared water responsibilities in these households. Closer inspection of our results confirms the households with men as water collectors are within the lower reported household income brackets with 75% of these households earning monthly incomes of less than 3500 INR. Thus, the distribution of water collection tasks in our sample may be explained by the need for shared water responsibilities among males and females in very low-income households.

We also note that the results from this study may not generalise to the more affluent villages in the region or across India, as our sample is especially low-income, as commented on above. Thus, findings from this study will be mostly relevant to lower-income villages and households.

[**Table 1:** Survey respondent socio-economic characteristics]

Results also show approximately 13.9 % of the respondent sample has achieved higher education; however, the literacy level is less than the district average of 75.8-82.8% (depending on the source) (Directorate of Economics and Statistics, 2015; International Institute of Population Studies (IIPS), 2015).

Most households engage in agriculture as their primary source of income either as landowners growing crops on their own land (68%) or as laborers without landownership (29%). Interestingly, although most households (66%) have electricity and own a television, only 35% have a personal latrine on the household premise, closely matching the statistic (31%) for the region. This disparity between television and latrine ownership may reflect different costs associated with installing and maintaining televisions versus latrines in these villages; unfortunately, we did not collect data on these costs, so we cannot verify latrines are more expensive than televisions. However, the low levels of latrine ownership may also result from insufficient knowledge about the importance of sanitation. In the following section we report attitudes and behaviors relating to basic water and hygiene (WASH) characteristics; these are factors we expect will influence preferences for treated drinking water.

4.2 Water Collection and WASH Characteristics and Attitudes

Basic WASH characteristics are summarized in **Figure 2**. Villagers use either purchased water (source unknown) (13.7%) or groundwater sources (86.3%) accessed by various methods (e.g. community tap, tubewell, water treatment plant, private tap). Most households (60.4%) use a community water source as their primary drinking water source and 43% use the treatment plant on a regular or occasional basis. The total reported number of liters collected per day for drinking and cooking only, ranged between 4 liters-500 liters per household with an average of 44.4L per household and 7.7 liters per capita (lpc), well within the water minimums needed for daily drinking and cooking (5.5-15 lpd per person). Estimated lpc values greater than 20 lpc (9 households) most likely include uses other than for cooking and drinking in their collection values, but were included in the analyses (WWAP, 2015).

Results in **Figure 2** indicate basic WASH needs are not being met in many of these communities. Only 35% of households have a latrine on the premise and only 65% self-reported using soap to wash their hands. Many claim to perform some form of water treatment at home (38.9%), however most (84.8%) of this treatment includes passing water through a cloth as a filter. This method of household treatment could easily increase the concentration of microbes in household water depending on the cleanliness of the cloth and the handling methods employed. In fact, of the household purification methods used, only a home reverse osmosis (RO) unit or the addition of chemicals could potentially reduce fluoride concentrations.

[Figure 2: WASH Characteristics]

Overall, most residents have a positive view of their primary water source with 55%

reporting it was both of good quality and taste while only 3% thought it was poor in both of these categories. Furthermore, most respondents (71%) do not feel like the quality is changing for better or worse (see Supplementary Information, Table S 2).

4.4 Knowledge of Fluoride and Defluoridation Treatment Plant

Results in **Figure 3** show that very few respondents recognized fluorosis symptoms presented in pictures (31.4%) and of those recognizing the symptoms, only about half were aware that fluoride in the water was the cause (see Supplementary Information for more details).. This is a very surprising finding given that as part of the National Programme for Prevention and Control of Fluorosis in the 11th Five Year Plan extensive community outreach was reported. This plan includes a list of nine outreach activities to be carried out throughout the district, including daily TV and radio announcements, local performances throughout the year, the distribution and posting of informational posters, and district level seminars with doctors and practitioners (GOI, 2014). Evidence from our study suggests this outreach program failed to increase awareness about fluorosis or fluoride contamination in these villages.

We note however, that only 10.1% of the survey population reported having a family member suffering from visible skeletal or dental fluorosis, which might partly explain the low awareness levels. However, fluorosis can also manifest as joint pain in older individuals, which was not captured by the survey. If fluorosis symptoms were more evident among villagers, it is likely that awareness levels would be higher.

After the first series of questions, respondents were informed about fluoride, fluorosis, and the functions of the local treatment plant. This was followed by information about the handover process, by which the government-subsidized company-managed water treatment plant would be transferred to community-ownership (see Supplementary Information). Results show that only 17% of the respondents actually knew about this handover; again confirming that current outreach and information programs in these villages are severely lacking, as noted above. Perhaps most strikingly, of the 29 respondents that were either members of the GP or had a family member in the household that was part of the GP, only 11 knew the treatment plants were being handed over to the community. This indicates the lack of awareness among the villagers may not be due to a lack of communication at the village level between the GP and the residents, but rather, appears to occur at the point of contact between district officers and the GP. Clearly, community outreach as currently implemented is not working. In the absence of knowledge about the purpose of their local water treatment plant, villagers will have no incentive to collectively manage this shared resource. It is also possible that villagers do not value fluoride-free water, independent of awareness levels. Our study will help to clarify this question.

Finally, respondents were asked: "*How likely do you think it is that the community will successfully take over the operation and maintenance of the water treatment system without the private company?"* Despite having no prior knowledge about the hand-over, 43% of the survey population felt the handover would be successful. We expect that WTP or willingness to contribute time towards local water treatment plants will be influenced by the perceived likelihood of success.

[**Figure 3**: Fluoride and defluoridation treatment plant knowledge characteristics]

5. Willingness to Pay or Contribute Time for Water Treatment

This section presents estimates of the economic value to respondents of the long-term operation of their local water treatment plant, using three scenarios. **Table 2** presents summary WTP statistics for the three payment scenarios (histograms of values and explanation of outlier identification are available in the Supporting Information). Analysis of the zero contribution responses show that protest responses accounted for 6.6% and 4% of the WTPm and WTcT mechanisms respectively, while 13.9% of zero WTPc amounts were classes as protests (see discussion of protest responses in the Supporting Information).

Results show that approximately 87% of respondents were willing to make positive contributions of money (WTPm) or time (WTcT) towards the communally-accessible water treatment plant, whereas only 52.1% were willing to make a positive contribution towards the pay-per-container scheme (WTPc). A Chi squared test of proportions shows that the difference between WTPm/WTcT and WTPcis highly significant ($p<0.000$). Thus, our results indicate low levels of acceptance of the pay-per-container scheme. This is very interesting since pay-per-container schemes, such as water ATMs, are being deployed across rural India amid claims of growing popularity amongst users (Aiyappa, 2014; Gupta, 2014; Kapoor, 2015; Press Trust of India, 2014; TNN, 2016). Our preliminary findings suggest these claims may not be warranted. More research would be needed to identify acceptance levels among rural populations in other parts of the country.

To gain some insight into why villagers are less likely to state a positive WTPc for the pay-per-container scheme, we analyze the main (non-protest) explanations provided by respondents who state zero WTPm, WTcT, or WTPc. We find that the main reasons provided for zero WTPc include: ‘I cannot afford it’ (n=136, 68%) and ‘I don’t think I should have to pay for my water’ (n=27, 13.5%). While consistent with the main reasons provided for zero WTPm and WTcT (n=17, 33% and n=3, 6%, respectively), the proportions selecting these reasons for non-payment to the WTPc scheme are noticeably higher. However, we would expect, if respondents struggle to pay for water under one scheme, then they would also struggle under another scheme. In other words, we would expect similar numbers of respondents choosing zero contributions under both monthly and pay-per-container schemes. Our results suggest these zero WTPc values may represent a rejection of the scheme itself rather than low preferences for fluoride-free water. Further analysis shows that affordability is selected as the primary explanation for zero WTPc by respondents in the two lowest income brackets. It thus appears that the pay-per-container scheme is perceived as unaffordable and rejected outright mostly by villagers in the lower income groups. Further research might explore perceptions of water ATMs amongst different income groups, with a focus on perceptions of fairness and justice of pay-per-container mechanisms.

In the case of WTcT, the main reason provided by respondents who were not willing to contribute time toward the water treatment plant was, 'I don't have the time' (n=37, 68.5%) and this explanation was primarily associated with the lowest two income brackets (86.5% from the two lowest income brackets). This is interesting because labor contributions are often used in stated preference studies to identify the WTP of individuals who might highly value a resource but who cannot afford monetary payments (e.g. Abramson et al., 2011; O'Garra, 2009). In this case, it appears low income households are also time-constrained; in such contexts, where both time and money are limited, it would be useful to explore other potential numeraires that could be suitably used to capture preferences.

In terms of amounts contributed, summary statistics show, while many respondents did not agree to the WTPc scenario, those that did pledged a significant portion of their income (11.9% on average). If we compare the cumulative distribution functions for contributions under all scenarios as fractions of household incomes (see Figure S3a in Supplementary Information), WTPc is the steepest of all the scenarios. Roughly 40% of respondents pledged more than 5% of their household income in the WTPc scenario while only approximately 10% of respondents pledged more than 5% of their income in the WTPm. The WTPc scenario is largely unaffordable for most of the population.

Overall, results indicate the 'public good' scenarios (WTPm and WTcT) are more popular than the pay-per-use mechanism. We will identify and compare the determinants of preferences for these three different mechanisms using regression analyses in Section 0. This will allow us to identify the drivers of WTP or WTcT and to ascertain to what extent preferences for the different water schemes are motivated by the same factors.

[**Table 2**: Willingness to Pay or Contribute Time Summary Statistics]

5.1 Comparing and Aggregating Estimates

To compare estimates, these time contributions were converted into common metrics and comparable scales. To convert WTcT amounts into economic estimates, we used wage and leisure rates of time. The wage rate was calculated by dividing reported household income (**Table 3**) by the number of adults in the house and by an assumed 160 working hours per month (40 hours/week, 4 weeks/month) to achieve an hourly per person wage rate. This was then multiplied by the number of hours per day a person was willing to contribute and by 30 days to compute a monthly contribution. The leisure rate of time is one third of the wage rate, as identified by (Cesario, 1976). This is similar to conversion methods used in O'Garra (2009).

The second task involved converting WTPc values into monthly estimates. To do this, we take a conservative approach by assuming that the per-container scheme would mainly be used for drinking water (and not for cooking uses). Thus, to calculate the amount of drinking water that might be purchased per month from the pay-per-container scheme we assume that an adult requires 2 L/day (for drinking only) to sustain life (WHO, 2011) and a child 1.5 L/day, the number of adults and children within the household were multiplied by their respective volumes to get an approximate number of fluoride-free liters required per household per day. That volume was then divided by the 20 L container size quoted in the survey during the payment scenario and rounded up to the nearest whole number. This number of receptacles collected was multiplied by 30 days and the midpoint payment value selected on the WTPc scale was used to calculate an estimated monthly expenditure using the WTPc method.

Calculated daily, monthly, and annual contributions are presented in **Table 3**. Results show that, depending on the payment scheme used, WTP for water treatment plants ranges between 1.9% and 6.6% of household income (using mean values). This is comparable to findings in other studies of WTP for treated water (e.g. Abramson et al., 2011; Pattanayak et al., 2005) or improved water sources (e.g. Echenique & Seshagiri, 2009; Vasquez, 2014), and accords with the "5% rule of thumb" (McPhail, 1993).

Welfare estimates from WTcT calculated using the leisure rate of time, are comparable to WTPm estimates, with both measures, on average, accounting for less than 3% of a household's income. WTPc contributions represent the highest percentage of income at 6.6%. This violates most measures of affordability which typically range between 1% - 5% of household income (Fankhauser & Tepic, 2007; Sebri, 2015; The World Bank

Water Demand Research Team, 1993; USEPA, 2002). Yet, previous research has concluded households are willing to exceed these affordability measures when marginal improvements are made to quantity, quality, and pressure of the current water supply (Echenique & Seshagiri, 2009). Estimates from the WTPc scheme are quite different to those from the monthly mechanisms, as respondents are being asked for their preferences for a private good which only payees can access. Thus, preferences for the WTPc scheme may reflect other motivations that do not influence WTP or contribute time per month. For example, high WTPc values may reflect higher levels of distrust in the ability of the community to collectively manage the public good. Additionally, high WTPc values may indicate a lack of interest in becoming involved in resource planning as might be required for communally-managed schemes.

[**Table 3**: Summary of average pledged household expenditures for each willingness to contribute scenario]

6. Economic model

6.1 Interval regression analysis

We analyzed the determinants of mean WTP or WTcT using an interval regression model, which considers the interval nature of our data. The interval data model states that the probability that the true WTP of a respondent, with characteristics Y, lies in the interval $[BID_{L}, BID_{U}]$ is given by $\Phi (BID_{U} \mid Y) - \Phi (BID_{L} \mid Y)$, where WTP is assumed to follow a distribution with a standard normal cumulative distribution function (Φ). A normal distribution was assumed for all three models, as it performed better than the more commonly-used lognormal distribution. The model is estimated using maximum likelihood estimation (for more details on interval regression model see Cameron and

Huppert, 1989). Data was analyzed using Stata/IC.

Explanatory variables were expected to influence elicited preferences include: knowledge about fluorosis and fluoride-contamination; a firsthand experience with fluorosis in the family, perceptions of current water quality; and perceived ability to personally deal with fluoride exposure (via household purification and/or use of the defluoridation treatment plant). Demographic variables that typically impact contributions to a public good include age (-), income (+), education (+), and gender (female=+) (Casey, Kahn, & Rivas, 2006; Polyzou, Jones, Evangelinos, & Halvadakis, 2011). We also expect, for the monthly mechanisms (WTPm and WTcT), preferences will be positively influenced (although at a decreasing rate) by the amount of water collected per household per day. For the WTPc mechanism we used a slightly different metric (number of containers required per day) as payments are directly tied to the 20L collection container of the scenario design. We expect this influence to be negative, reflecting decreasing marginal benefits per container. Effects associated with the different villages are controlled for by including village dummies in the regressions. Results from the three regression models are presented in **Table 4**.

[**Table 4**: Interval regressions on willingness to pay per for the three payment schemes: WTPm, WTcT, and WTPc]

Results in **Table 4** show the determinants of preferences for the three schemes vary widely, and there is no one common influence on preferences across all schemes. This suggests that these scenarios are not perceived to be close substitutes for each other and, instead, may be seen as providing quite different water provision services; however, there are some commonalities. For example, income has a significantly positive influence on WTP under both monetary mechanisms (WTPm and WTPc), as expected, whilst the ratio of children to adults in a household has a positive effect on both WTPm and WTcT. We will describe and compare results of these three models, focusing first on the influence of socio-economic characteristics and then on the influence of WASH characteristics and knowledge of fluoride on preferences.

6.1.1 Impact of Socio-economic Characteristics

Results in **Table 4** show the socio-economic determinants of contributions to the three payment mechanisms are quite different. Thus, Hindu respondents from higher-income households with more children (compared to adult numbers) and higher levels of latrine-ownership have higher WTPm. Meanwhile, older respondents from households with more children prefer to contribute time (WTcT) towards the water treatment plant. And WTPc is higher among Hindu respondents who were born in the village and who are from higher-income, smaller households which contain a member of the village council amongst their number.

These differences provide some insight into how respondents perceive of the different mechanisms and the underlying motivations for supporting and contributing towards each one. For example, both public good scenarios attract higher contributions of time or money from respondents in households with more children. This is an expected result, however, we might have anticipated this variable to also influence WTPc, yet this is not the case. Indeed, it appears preferences elicited under the WTPc scheme are influenced by factors unrelated to concerns about health (whether of adults or children), attitudes towards water, or WASH behaviors. Rather, positive preferences for the pay-per-container scheme appear to be influenced mainly by inter-personal or governance related issues.

As noted above, WTPc is positively influenced by the presence of a Gram Panchayat member in the household (this has no effect on preferences for the other schemes); this could reflect greater awareness amongst households with village council members of the limitations and challenges of organizing and enforcing monthly payments (or time contributions) for a public resource open to all. Alternatively, it may indicate a lack of interest in organizing payments and management of such a communal system. We also note village tenure has a positive influence on WTPc - and no influence on preferences for the public good schemes - which might indicate a willingness to exclude 'newcomers' to the community who might be perceived as potential free-riders; however, this is purely speculative and we cannot confirm whether this is indeed the case. Further research on the interaction between trust, social cohesion, and water access will be vital to identify the implications for equitable access to water of the rapidly expanding implementation of water ATMs across India.

Finally, willingness to contribute towards water treatment was no higher amongst females compared to males; this is unexpected as females are often found to be more concerned and hold higher preferences for clean water (Alfredo, Lawler, & Katz, 2014). Our results suggest preferences for treated water are not gendered.

In the following section, we discuss the impacts of water collection, WASH, or fluoride and treatment knowledge variables on preferences.

6.1.2 Impact of water collection, WASH, and fluoride and treatment knowledge

The following discussion will focus primarily on the two public-goods models, WTPm and WTcT. This is because, as noted above, none of the water collection, WASH, or fluoride-related knowledge variables were significant determinants of WTPc. As results show, households already using the treatment plant as the main source of drinking water would have a higher WTP (of INR17.15) to sustain the resource into the long-term (see **Table 4**). Additionally, a belief that the handover will be successful increases WTPm by INR10.75 per month. The positive influence of both using the treatment facility as well as having confidence in its success post-handover suggests respondents were thinking about the WTPm contributions as a long-term investment in a resource. Households collecting high volumes of water per day are also poised to benefit the most, as reflected in the positive, significant impact of household water consumption on WTPm.

Meanwhile, those who spend time using household treatment to treat their water are less willing to contribute time towards communal treatment. This is reasonable, as time spent at home purifying the water and time spent contributing towards the upkeep of the treatment plant may be considered close substitutes under certain conditions. We note, however, that most household purification conducted (86% use cloth filtration) would have no impact on the fluoride concentration of the water. Although education outreach is supposedly conducted in these villages as part of the treatment facility implementation process, it is not effective at providing useful information that improves health-related behaviors, such as household purifiers.

Results also show that recognition of fluorosis symptoms positively influenced WTcT. Over three-quarters of respondents recognizing fluorosis symptoms belong to the lowest two income brackets, potentially indicating in-kind contributions are a more “affordable” point of entry to accessing improved water. Interestingly, prior awareness of fluorosis symptoms and exposure to fluoride and fluorosis (measured through village tenure), had no significant impact on WTPm. Finally, experience of waterborne illnesses in the past year had no significant impact on WTPm.

7. Economic sustainability

Values obtained from different organizations in the area reported a wide range of costs, 223-754 INR/day, to operate these electrocoagulation plants given yearly operation expenses (see Supporting Information for more details). Considering only the proportion of each village’s population that would be willing to pay ([**Table 2**) and the average daily contributions estimated for the WTPm and WTPc scenarios (**Table 3**) as well as similar calculations for the median contributions per day, the critical community size is calculated for each payment scheme and presented in [**Table 5**. [**Table 5:** Critical village population size to achieve cost recovery at two estimated daily operation values]

Given the size distribution of our villages, two of the eleven are smaller than the critical village size for the WTPm payment scheme at the lowest cost projection. The WTPc payment scheme requires a smaller village size to be economically viable, even given the low WTP potential. However, both payment schemes would fail in most of our study villages if the technology costs closer to 755 INR/day to operate. This estimated daily cost would requires 360-417 households in the WTPm scheme and 174-192 households for WTPc, a size requirement only met by 1/11 and 6/11 villages respectively. This simplification does not account for income influences on the ability to pay for treatment. In the regression analyses, income was a factor on how much people were willing to pay in both the WTPm and WTPc scenarios. A majority of households (80%) earn less than 5000 INR, 31% earning 1000 INR or less, with the average income for the entire sample at approximately 4000 INR. Therefore, even though the WTPc scenario has a greater ability to meet the price recovery, the ability of a community to reach the quorum necessary to cover the daily expenses is more challenging.

If we consider possible time contributions by villagers - particularly, lower-income households - towards the operation and management of the water treatment plant, then this may solve part of the finance problem. Operator salaries could be partly substituted with labor contributions by individuals from low-income households, which could potentially save 500-1200 rupees per month assuming 25% and 50% reductions in operator salaries (for corresponding reductions in labor time).

8. Conclusions

This paper reports results of a CV survey of preferences for communal water treatment plants in rural Maharashtra. Preferences were elicited using monthly monetary contributions, monthly time (labor) contributions and payments per-container. We find that respondents are willing to pay an average of 72.4 INR per month or contribute 1.3 hours per day towards the operation and maintenance of the communal 'public good' version of the water treatment plant. Welfare estimates calculated from time contributions (WTcT) using the leisure rate of time are comparable to the amounts pledged in the WTPm scenario, with the former representing 1.9% and the latter representing 2.8% of household income. This is well within the bounds of the 5% 'rule of thumb' which typically describes the maximum amount a rural subsistence household should pay for water (Fankhauser & Tepic, 2007; Sebri, 2015; The World Bank Water Demand Research Team, 1993; USEPA, 2002).

Responses to the pay-per-container scheme (WTPc) however, were very different. Firstly, this payment mechanism was far less acceptable to respondents, with almost half the sample stating zero WTPc. In contrast, over 85% of respondents stated positive WTPm or WTcT values, suggesting a rejection of the privatization scenario. If respondents were indifferent to the per-container payment approach, then we would have expected similar proportions stating positive WTP, albeit adjusted downwards to account for household size and water consumption levels. This was not the case. Furthermore, despite the high proportion of zero WTP for the pay-per-container scenario, estimated monthly payments were significantly higher for this scheme (representing 6.6% of household income) than WTP estimated using the other payment mechanisms,

This is a very important result as water ATMs are growing in popularity across India and political actors are moving towards implementing them within rural communities; yet, the acceptability of these schemes by the community remains largely unknown. In addressing this research gap, we conclude that pay-per-container models of water provision may require different development and implementation strategies than the more commonly-used communal water treatment schemes used in many parts of the world, such as the Vidharba Region of Maharashtra. Through analysis of the WTP survey responses and interval regression analyses, we conclude that the determinants of preferences for the WTPc scheme are quite different from those influencing preferences for the public good model of communal treatment plant. Our findings suggest that concerns about health and water play a significant role in determining preferences for treated water as a public good, whilst WTPc appears to be motivated by social concerns that are unrelated to water or health. Our findings also indicate that there is a widespread lack of awareness and knowledge regarding fluoride, fluorosis, and the functionality of the local treatment plants. This raises concerns regarding the actual implementation of the outreach and educational schemes outlined in the water development policy. In the absence of knowledge about the role of the local water treatment plant, it cannot be expected that local residents will contribute time or money towards operation and maintenance. Thus, more work needs to be done to inform local villagers about development projects being implemented in their communities, if this investment is actually to result in health improvements and associated economic development. Finally, using these estimated values, we identified the economic viability of the larger-scale deployment of communal water treatment plants across the state. Our findings show that the long-term economic viability of the electrocoagulation treatment plants implemented in these communities is tenuous. Clearer cost delineation related to these treatment plants are required as well as more detailed accounting of actual payments made to village operators versus reported values by contract companies. Using the range of potential daily costs to successfully operate the treatment plant and the monetary contributions from the contingent valuation survey, some villages are unable to meet the lowest cost scenarios. These villages are likely to be unsuccessful in maintaining daily operation of their treatment plant without additional financial assistance.

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[Figure 1: Location of 11 project villages within the Yavatmal District in eastern Maharashtra.]
[Figure 2: WASH Characteristics]
[Figure 3: Fluoride and defluoridation treatment plant knowledge characteristics]

[**Table 1:** Survey respondent socio-economic characteristics]
[**Table 2**: Willingness to Pay or Contribute Time Summary Statistics]
[**Table 3**: Summary of average pledged household expenditures for each willingness to contribute scenario]
[**Table 4**: Interval regressions on willingness to pay per for the three payment schemes: WTPm, WTcT, and WTPc]
[**Table 5:** Critical village population size to achieve cost recovery at two estimated daily operation values]

Table 1: Survey respondent socio-economic characteristics

Respondent characteristics (n=424)	Study Characteristics	Yavatmal Population
Gender (% female)	55.9	48.8
Average age	36.5 (0.67)	n.d.
Highest education level (%)		
No schooling	29.3	n.d.
Primary schooling (grade 1-4)	16.8	n.d.
Higher secondary schooling (grades 11-12) or higher	13.9	n.d.
% of respondents that can read and write	62.5	75.8 – 82.8
% of respondents always lived in this village	68.9	n.a.
% Hindu religion	90.3	81 [a]
Household characteristics		
Household size (mean number of people)	6.3 (0.14)	4.7 [c]
Number of children (<10 years old) per household (mean)	1.4 (0.07)	n.d.
Gross monthly household income (mean, INR)*	4,090 (3993)	5,289 [b]
% landowners growing crops on own land	68%	
% laborers without land ownership	29%	
% latrine on premises	35.4	31.2 [c]
% Households with water source on premises	23.6	24.0 [d]
% of households that own a television	65.8	n.d.
% of households with electricity	66.0	70.0 [c]
% of households that contain a member of the Gram Panchayat	6.9	n.d.

Figures in parenthesis () are standard deviations; **13 refused to answer, missing values were imputed using the *average income for the village, income taken as mid-interval of income categories; [a] This figure is from the 2001 Census; [b] Statistics for Maharashtra, year 2005-6. Source: IIPS (2007); [c] Source: MIDC (2012) 'Maharashtra Districts'; [d] Statistics for 2001. Source: UNICEF/ via http://knoema.com/INDAT2012/india-development-indicators-2012

Table 2: Willingness to Pay or Contribute Time Summary Statistics

Summary statistics (n=424)	**₹/month** [a]	**hrs/day**	**₹/container**
Willingness to pay > 0 (% of sample)	86.7	87.3	52.1
Willingness to pay = 0, protest (% protests in sample)	6.6	4.0	13.9
Mean WTP (s.d.) (INR or hours) †*	72.4 (56.0)	1.3 (0.81)	7.7 (11.4)
Median WTP (INR or hours) †*	62.5	1.5	7.5
Minimum/Maximum (INR or hours)*	0/500	0/6.5	0/100
Average conditional WTP (WTP>0) (s.d.)* (INR or hours)	77.9 (54.3)	1.4 (0.74)	14.1 (12.1)
Median conditional WTP (WTP>0)* (INR or hours)	62.5	1.5	12.5
Number of outliers (percent of population)	1 (0.2%)	2 (0.5)	47 (11.1%)
Number of respondents †*	394	405	318

† protests excluded; *payment outliers excluded; [a] one respondent did not answer this question

Table 3: Summary of average pledged household expenditures for each willingness to contribute scenario

WTP estimates (₹)*	**WTPm***	**WTcT (wage rate)**	**WTcT (leisure rate)**	**WTPc†**
WTP per day [a]	2.4	7.7	2.6	8.3
WTP per month [b]	72.4	232.0	77.3	249.3
WTP per year [c]	868.9	2784.5	928.2	3033.1
Average % of HH income	**2.8**	**5.8**	**1.9**	**6.6**

*no protests, no outliers; a for WTPm and WTcT scenarios, WTP per day calculated using WTP per month and dividing by 30; [b] WTPc values were multiplied by 30 days. [c] WTP per month multiplied by 12 for all payment scenarios; †Conservative estimates of drinking water only needs (2 L/day for adults and 1.5 L/day for children) were used in these estimates (full explanation contained in the Supporting Information).

Table 4: Interval regressions on willingness to pay per for the three payment schemes: WTPm, WTcT, and WTPc

	WTPm		WTcT		WTPc	
	β	(se)	β	(se)	β	(se)
Socio-economic Characteristics						
Gender (1= female)	3.275	5.448	-0.068	0.086	1.603	1.161
Age	0.002	0.198	**0.009*** **	0.003	-0.018	0.043
Education (higher secondary and above=1, all others=0)	-3.816	7.514	0.068	0.121	1.314	1.641
Village tenure (1=always lived in this village, 0=all others)	6.700	5.833	-0.029	0.090	**2.469***	1.274
Religion (1=Hindu, 0=all others)	**18.47****	9.183	0.055	0.147	**4.143***	2.174
Household child ratio (children/household count)	**37.70*****	13.820	**0.702*****	0.217	-2.179	2.968
Household size (consistently living in household)	-0.721	0.947	0.016	0.015	**-0.580****	0.279
Reported monthly income (missing values imputed) (INR/1000)	**2.94*****	0.684	0.016	0.011	**0.631*****	0.138
Households with a latrine on premises	**13.37****	6.322	0.110	0.099	0.808	1.332
Household contains a member of the Gram Panchayat (1=yes)	14.640	10.320	0.091	0.161	**5.124****	2.260
Water Collection and WASH Characteristics						
Reported liters per day collected per household	**0.260*****	0.059	0.000	0.001	---	
Estimated number of 20L containers required (WTPc scenario)	---		---		4.175	2.963
Use of treatment plant as primary source (1=treatment plant, 0=all others)	**17.15****	8.568	-0.075	0.124	2.041	1.797
Use a household purification system	1.215	5.763	**-0.246*****	0.091	-0.440	1.241
Household member had a waterborne illness in past year (1=yes)	-6.458	6.765	0.165	0.105	1.635	1.402
Rate water quality as good (1=good, 0=all other ratings)	**-14.33****	5.711	-0.047	0.090	-1.223	1.202
Knowledge of Fluoride and Defluoridation						

Recognize dental and skeletal fluorosis images (1=yes, 0=no)	1.412	6.693	**0.187***	0.103	-1.337	1.403
Feel the handover process will be successful (1=yes, 0=no)	**10.75****	5.201	0.126	0.083	0.532	1.097
village dummies included (eleven)						
constant	-10.920	19.040	0.308	0.300	-1.478	4.430
N	386		397		318	
Prob>chi2	0		0.004		0	

[**Table 5:** Critical village population size to achieve cost recovery at two estimated daily operation values]

	223 INR/day	**755 INR/day**
WTPm (avg)	106	360
WTPm (med)	123	417
WTPc (avg)	52	174
WTPc (med)	57	193

ENDNOTES

[i] There are different types of elicitation method in contingent valuation, the main ones being dichotomous choice (DC), and payment ladders. The payment ladder approach has been found to have advantages over DC because it less susceptible to anchoring and 'yea-saying' (Soeteman, van Exel and Bobinac, 2017; Zhongmin et al., 2006; Champ et al., 2003) and is cognitively less-demanding (Ready, Navrud & Dubourg, 2001).